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ORIGINAL RESEARCH

Knowledge retention when using e-learning to supplement face-to face training of first responders

Igor Karnjuš[1], Dominik Simčič[2], Boštjan Žvanut[1,*]

[1]Faculty of Health Sciences, University of Primorska, 6310 Izola, Slovenia
[2]Health Center Ilirska Bistrica, 6250 Ilirska Bistrica, Slovenia

***Correspondence**
bostjan.zvanut@fvz.upr.si
(Boštjan Žvanut)

Abstract

Training of first responders in cardiopulmonary resuscitation and the use of the automated external defibrillator should be designed to maximise retention of acquired knowledge. The objective of this study was to investigate whether the use of e-learning as a supplement to face-to-face training can lead to better knowledge retention among training participants than face-to-face training alone. A quasi-experiment was conducted between May 2017 and February 2018. Both the intervention and control groups participated in two days of training (totalling ten hours). The intervention group also participated in an additional 15-minute e-learning course. The knowledge of all participants was assessed immediately after the training and six months after the training with a paper-based test. The use of an e-learning course to supplement face-to-face instruction resulted in a significant positive improvement in knowledge retention. After a period of six months, a statistically significant decrease in test scores was observed in the control group ($p = 0.005$), in contrast to the intervention group ($p = 0.114$). The use of e-learning as a supplement to face-to-face training could be a valid approach to improve knowledge retention among course participants.

Keywords

E-learning; supplementation; First responder; Knowledge retention; Cardiopulmonary resuscitation; Automated external defibrillator

1. Introduction

Numerous studies suggest that bystander cardiopulmonary resuscitation (CPR) and early defibrillation are critical factors in the survival of individuals who have suffered an out-of-hospital cardiac arrest (OHCA) before the arrival of emergency medical team (EMT) [1, 2]. However, studies from the last decade show that only a small percentage of bystanders are willing to assist a person in sudden cardiac arrest [3]. Lack of confidence, fear of infection during mouth-to-mouth resuscitation, and inadequate training seem to be the main deterrents [4]. Although OHCA is associated with a low survival rate (between 2 and 11%), its early recognition and early application of CPR and defibrillation within the first three to five minutes has been shown to increase survival by 50–70% [5]. Therefore, a broadly educated population could be a potential solution. In the last two decades, several European countries have introduced a profile of Certified First Responders (CFRs), *i.e.*, individuals who are not medical professionals but are trained and competent in performing life-saving CPR [6, 7]. The use of CFRs is one method that has been developed to address this challenge, particularly for rural areas where EMT response times are somewhat longer than in urban areas.

This type of course usually consists of a theoretical and a practical part, where participants respond to scenarios in small groups under the supervision of an instructor using simulators. In fact, studies have shown that practising on simulators under the supervision of an instructor is the most effective training modality for learning CPR [8, 9]. However, traditional face-to-face instruction entails some unfavourable factors, such as the cost and logistics associated with providing of classrooms and qualified instructors, the need to share simulators, and the limited practice time and potential anxiety of students [4]. Moreover, in recent decades we have been confronted with new diseases, such as the current situation with the COVID-19 pandemic, where face-to-face learning methods are not recommended or are difficult to implement. Alkhailaileh *et al*. [10] state that CPR skills can be improved by using blended learning approaches as a combination of face-to-face instruction, an interactive online course, and self-learning using textbooks, computer-based lessons, and videos. Educational psychology recognises the fact that individuals prefer different learning methods, as no single teaching method can meet all learning needs [11].

The changes in education brought about by the COVID-19 pandemic provide an opportunity to benefit from e-learning in the form of additional activities aimed at refreshing CPR skills and knowledge acquired in face-to-face training. In this study, we refer to e-learning as an educational approach that is an educational model "based on the use of electronic media and devices as tools for improving access to training, communication and interaction, and that facilitates the adoption of new ways of understanding and developing learning" [6]. E-learning has been shown to be a viable teaching method to support and supplement CPR courses for healthcare professionals in remote areas [12]. Alkhalaileh *et al*. [10] emphasised that e-learning reduces the time required for CPR training compared to the conventional approach when the content is well-defined and focused. In addition, several studies based on an experimental design measuring knowledge retention by comparing blended or full online e-learning training with traditional CPR face-to-face training have shown that e-learning leads to knowledge comparable to that acquired through traditional training [4, 13–15]. However, none of these studies used e-learning to supplement face-to-face training. In the study by Perkins *et al*. [16], e-learning was used as a supplement to traditional training, with the intervention group receiving additional training through an e-learning simulation programme prior to traditional training. Their results indicate that there were no significant differences in learning outcomes measured immediately after the course. Unfortunately, no further assessment of knowledge retention was conducted in this study.

An extensive literature search revealed no studies on the effectiveness of using e-learning to teach CPR procedures and the use of automated external defibrillator (AED) to CFRs. Therefore, the objective of this study was to test the effectiveness of e-learning in teaching CPR using AEDs. We hypothesised that the use of e-learning as a supplement to face-to-face training would result in better knowledge retention among participants than face-to-face training alone.

2. Methods

2.1 Study design

A quasi-experiment was conducted (Fig. 1) in which participants were randomly assigned to two groups. First, both groups participated in a two-day, 10-hour training course consisting of two sections: (1) traditional lectures on emergency medical assistance, unconsciousness, basic CPR procedures in adults/children, use of AED, airway obstruction, and haemorrhage; and (2) participation in scenarios in which the above procedures were presented in a simulated environment. Both groups received the same printed study material. Immediately after the end of each two-day training session, the intervention group participated in an additional 15-minute e-learning course completed individually on a computer. Following this, both groups completed a paper-based test. Data were collected at three equivalent training courses held 19 and 20 May 2017; 20 and 21 October 2017; and 16 and 17 February 2018. Each training course was attended by 16 participants: eight in the intervention group and eight in the control group. Six months after the training, both groups were invited to participate in a retest. During the time between the test and the retest, the e-learning course was unavailable and participants were unable to print or save any portion of the e-learning material. Participants in the control group attended the e-learning course after the retest. The training and testing were conducted according to the guidelines of the Slovenian Society of Emergency Medicine by certified, competent trainers: one physician (general practitioner), three registered nurses (RNs), assisted by one nursing technician.

2.2 Instruments

To assess the knowledge of the course participants in the test and the retest, eight out of ten items of the official examination of the Slovenian Society of Emergency Medicine were used in both phases of the study. The items included in the study were: (1) Sudden Cardiac Arrest-Symptoms and Recognition, (2) Consciousness Check, (3) Rescue Breathing Performance, (4) Chest Compressions Technique (Location and Hand Position), (5) Chest Compression Ratio Performance, (6) Using an AED, (7) Defibrillation in Children and Adults, (8) Performing Emergency Ventilation in a Child. All items were scored as correct (1 point) or incorrect (0 points). Because this examination is an official assessment instrument, it is not possible to present the items publicly. The maximum score for the test was eight points.

The e-learning course was developed for the purposes of this study according to the principles of guided activity, reflection, feedback, and pacing outlined by Moreno and Mayer [17]. It was designed as a self-paced guided activity, with an avatar guiding participants through 73 screens. Five videos and 26 custom-made photos from previous training sessions were used along various icons to represent different situations/procedures. Five single-choice questions, eight multiple-choice questions, one pair-matching task, and two correct order questions were included, each accompanied with explanatory feedback to encourage participants to think about their answers. To avoid cognitive overload of the participants [18], the items in each screen were carefully and systematically selected. To reduce the bias of the study, special care was taken in the design of the e-learning course to avoid directly addressing the questions used in the official exam. The e-learning course was developed using the tool Courselab (ver. 2.4, WebSoft Ltd., Moscow, Russia) [19].

2.3 Sample

The convenience sample consisted of 48 participants, potential CFRs from the southwestern part of Slovenia, who voluntarily participated in the training. The implementation of CFRs network was still in its infancy at the time of the study. In an effort to recruit as many participants as possible for the training of CFRs, the Red Cross of Slovenia instructed the associations of volunteer firefighters at the level of individual municipalities to call on their members to participate in the above training. None of the participants came from a medical or other health profession. None of them had attended an additional certified basic life support course prior to the study. All the study participants encountered this content only in connection with obtaining a driver's license.

When calculating the sample size, a minimum number of 23 participants in both groups was recommended (see subsection 2.4 for details). Participants were randomly assigned to the intervention and control groups by generating a random binary

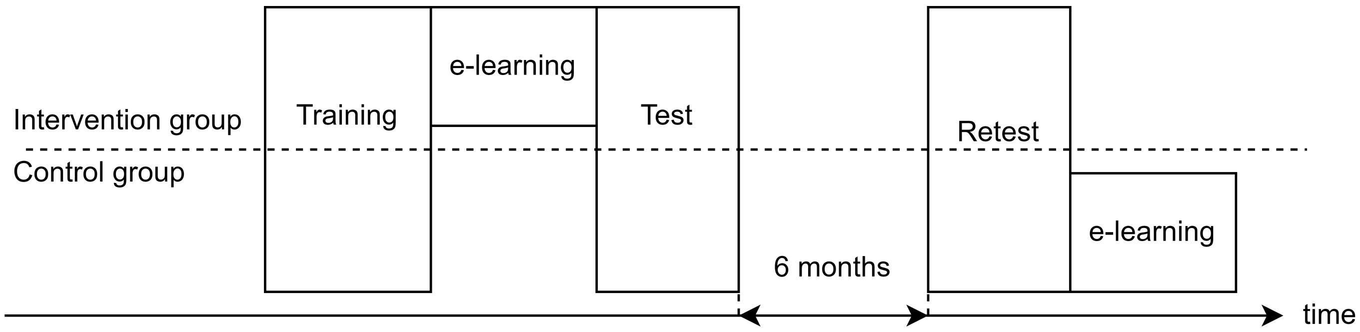

FIGURE 1. Study design.

digit using Microsoft Excel (ver. 2016, Redmond, WA, USA). Despite considerable efforts (*e.g.*, multiple phone calls, email invitations), only 33 participants accepted the invitation to participate in the retest. Table 1 shows the descriptive statistics of participant demographics. No statistically significant differences were found in gender distribution in the intervention and control groups in both the test and retest phases (test: $\chi^2(1) = 1.34$, $p = 0.247$; retest: $\chi^2(1) = 0.79$, $p = 0.373$) and in age (test: $t(46) = -0.28$, $p = 0.777$; retest: $t(31) = -1.34$, $p = 0.189$).

2.4 Statistical analysis

First, univariable data analysis with normality tests was performed. Because of the non-normality of the distributions of the test results, non-parametric statistical tests were applied. To test for the differences in responses between the intervention and control groups in both phases of the study, the Mann-Whitney U test was applied, whereas the Wilcoxon signed-rank test was used to test for the differences in responses between both phases of the study. In addition, multilevel modal analysis for repeated response was used to evaluate the effect of group (control/intervention) on test results in both phases of the study. Data analysis was performed using IBM SPSS (ver. 22.0, Armonk, NY, USA), while statistical power was calculated using GPower (ver. 3.1.9.2, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The statistical significance level was 0.05 and the minimum statistical power was 0.8. Estimation of the minimum sample size for each group was based on priori calculation of statistical power for the Wilcoxon signed-rank test, considering minimum statistical power and assuming a medium effect size (d = 0.5). Due to the dropout of some participants in both groups, a post-hoc statistical calculation was also performed.

3. Results

The results of the Mann-Whitney U test presented in Table 2 show no statistically significant difference in the results between the intervention and control groups in the test phase ($p = 0.768$). On the other hand, a statistically significant difference in test results between the intervention and control groups was found in the re-test phase ($p = 0.044$). In this phase, the intervention group achieved better results than the control group as the difference in median scores was two points. The results of the intervention group had a lower interquartile range (IQR = 2) than those of the control group (IQR = 3). The statistical power was 80.7%.

Table 3 and Fig. 2 show the comparison of test and retest results for the intervention and control groups. The results of the Wilcoxon signed-rank test show a statistically significant difference in test scores between the two phases for the control group ($p = 0.005$), with the median score and Q_1 decreasing by two points and Q_3 decreasing by one point. The statistical power was 89.96%. In contrast, for the intervention group, no statistically significant difference in test results ($p = 0.114$) was found between the two phases. The results of multi-level modal analysis for repeated responses indicated a significant fixed effect of the group (control/intervention) on test results in the re-test phase (MD = 1.50, $p = 0.014$, 95% CI (0.32, 2.68)), while the aforementioned effect in the test phase was not significant (MD = 0.04, $p = 0.874$, 95% CI (−0.48, 0.57)).

4. Discussion

Our results provide interesting insights into the outcomes of CPR and AED training of CFRs. It appears that the introduction of an additional pedagogical modality—in our case, an e-learning course—can lead to better knowledge retention. This is crucial because poor retention of knowledge in this population may be one of the factors contributing to the low survival rate after cardiac arrest [20]. According to Zieber and Sedgewick [21], there is a lack of strong evidence to determine the factors that contribute to successful knowledge retention, as activities aimed at improving knowledge retention are based on assumptions rather than more rigorous studies. Our study seeks to address this gap by providing valid evidence on the impact of e-learning as a supplementation to face-to-face training on knowledge retention among CFRs.

According to our results, the intervention group did not perform better than the control group immediately after training. Interestingly, although the intervention group had received additional training in the form of e-learning before the test, there were no significant differences in the results in the test phase of the study compared to the control group (Table 3). Similar results were also found in comparable studies [13, 16] in which participants in the control group received face-to-face training, and participants in the intervention group additionally participated in a serious game before the test. In neither study were significant differences in the results of the test administered immediately after the face-to-face training. It is therefore not surprising that the concluding remarks of both

TABLE 1. Descriptive statistics of participant demographic data.

Data	Test (n_t = 48)	Retest (n_r = 33)
Sample size n (%)		
Intervention group	24 (50.0%)	18 (54.5%)
Control group	24 (50.0%)	15 (45.5%)
Gender n (%)		
Men	26 (54.2%)	16 (48.5%)
Women	22 (45.8%)	17 (51.5%)
Age (years)		
Mean	38.9	39.5
SD	10.4	9.8
95% CI	(35.96, 41.84)	(36.16, 42.84)

Note: CI: Confidence Interval.

TABLE 2. Comparison of test results between the intervention and control groups in both phases of the study.

	Group					
	Control		Intervention		Mann-Whitney U test	
Phase	n	Me (Q_1–Q_3)	n	Me (Q_1–Q_3)	U	*p*
Test	24	6.5 (6–8)	24	7 (6–8)	274.5	0.768
Re-test	15	5 (4–7)	18	7 (5–7)	80.5	0.044

Legend: Me = Median; Q_1 *= Quartile 1;* Q_3 *= Quartile 3.*

TABLE 3. Comparison of test results between the test and retest phases.

		Phase		Wilcoxon signed rank test	
		Test	Retest		
Group	n	Me (Q_1–Q_3)	Me (Q_1–Q_3)	Z	*p*
Control	15	7 (6–8)	5 (4–7)	−2.777	0.005
Intervention	18	7 (6–7)	7 (5–7)	−1.582	0.114

Legend: Me = Median; Q_1 *= Quartile 1;* Q_3 *= Quartile 3.*

studies emphasize the challenge of finding the optimal way to implement e-learning in such training courses. Other similar studies assess participants' knowledge acquisition immediately after training by comparing face-to-face training with blended learning or e-learning alone. In most studies, the outcomes of participants in e-learning or blended learning were comparable to those of participants attending face-to-face training alone [4, 14, 15, 22–24]. This is consistent with our study, as no significant differences were found between the intervention and control groups in the test phase, *i.e.*, immediately after the training (Fig. 2, Table 2). However, Moon and Hyun [25] reported better results for the blended learning group than for the face-to-face learning group. This difference can be attributed to several factors: *e.g.*, the quality of the design of their blended training, the willingness of the participants to use information and communication technology, *etc.*, which is beyond the scope of this article. Interestingly, none of the studies that looked at the use of e-learning in CPR and AED training reported that participants in the face-to-face training group performed better than participants in the e-learning or blended learning group.

In contrast to the test phase, the intervention group achieved better results than the control group in the retest phase (Fig. 2, Tables 2,3, and multi-level modal analysis for repeated measures results), which confirms our hypothesis. These results are consistent with the first part of the study by Creutzfeldt *et al.* [26]. According to our results, there was a significant decrease between test and re-test results in the control group compared to the intervention group (Table 3). In addition, the intervention group achieved more consistent results in the retest phase, as the interquartile range (IQR = 2) was lower than that of the control group (IQR = 3). Other studies also indicate the positive effect of e-learning on knowledge retention [4, 15, 23]. However, due to significant differences in study design (*i.e.*, in both cases e-learning was used as a substitute for face-to-face training and not as a supplement to it, differences in the duration of knowledge retention measurement), no further comparisons with our study are possible.

The positive effect of knowledge retention can possibly be explained by Moreno and Mayer [17], according to which an additional representation of the same information, *i.e.*, supplementation in the form of e-learning, triggers additional

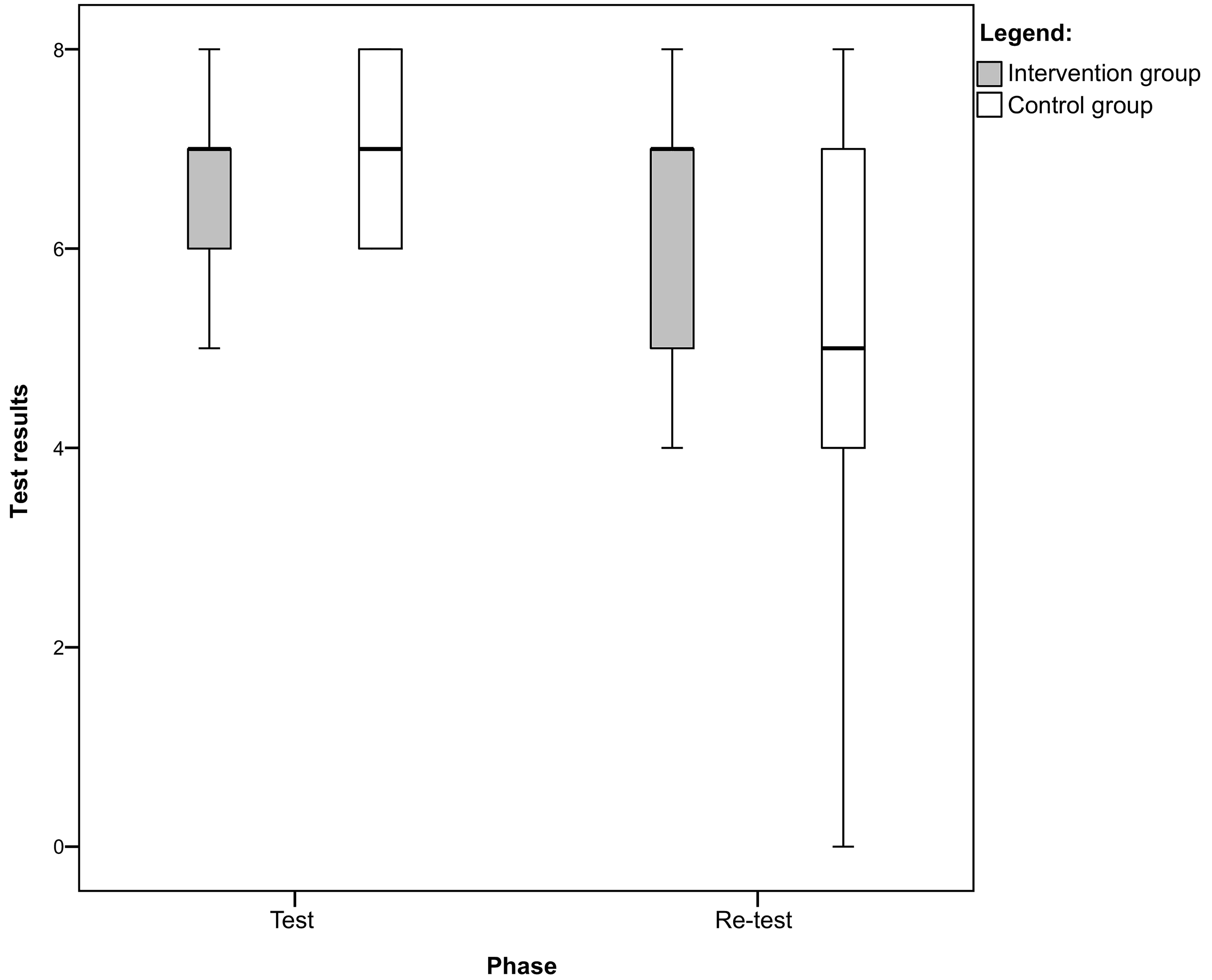

FIGURE 2. Box plot of test and re-test scores for the intervention and control groups.

mechanisms of knowledge integration and organization. We assume that episodic knowledge acquired during face-to-face training serves as a fulcrum for integration into long-term memory. Clearly, e-learning as a supplementation to face-to-face training could be a possible answer to the question raised in some studies [13, 16] about the optimal implementation of e-learning in CPR and AED training. Our study provides strong evidence for the use of e-learning as supplementation to face-to-face training. Although face-to-face training formed the core of the training, it provided a kind of "pre-training" for the supplementary e-learning session. Therefore, the principle of pre-training was also applied to some extent in the design of the training in the intervention group.

Although we did not investigate the effect of e-learning on the retention of practical skills in our study, some studies suggest that the use of e-content in the form of videos improves practical skills to some extent. Alam *et al.* [27] used videos in their study to teach a complex clinical skill such as airway management. Another study by Bock *et al.* [28] showed that the use of blended learning in the training of dental students in local anaesthesia improved their practical skills. However, without the accompanying elements that would be present in a real or simulated situation, acquiring the skills needed to manage CPR may be limited. For these types of skills, any form of cognitive learning, whether in isolation or in combination, can lead to performance improvements, as shown by Alam *et al.* [27]. However, they have limited potential for developing the ability to apply this knowledge in dynamic situations and the more psychomotor aspects of the task. Therefore, it is unlikely that cognitive teaching approaches such as e-learning, even when supplemented with instructional design strategies, are unlikely to fully replace hands-on training. Rather, they can be viewed as supplementary learning tools to prepare for learning in a real or simulated clinical situation. Even though, the above studies demonstrate the positive effect of blended learning on improving practical skills, a systematic review by George *et al.* [29] the quality of the evidence supporting this effect as low. Therefore, further studies in this area are needed.

In this study, e-learning was scheduled in the period after the training for the intervention group. Participants were not able to properly control the time needed to learn the new information, thus diminishing the benefits of self-paced learning, an important principle recommended by Moreno and Mayer [17]. Therefore, it will be interesting to compare the knowledge retention of the participants in a fully self-paced e-learning versus scheduled one as used in our study. Moreover, the e-learning used in our study was primary designed to be used as a self-paced learning tool that does not require the active participation of the instructor. However, according to Hsieh and Cho [30], instructor-student interactive e-learning can outperform self-paced e-learning. Therefore, further studies should also consider this option in designing e-learning courses for first responders and consider different ways of instructor-student interaction (synchronously via video conferencing, asynchronously by using different e-learning tools such as discussion boards, assignments, *etc.*).

The main limitation of the current study concerns the relatively small sample size. Unfortunately, some participants did not participate in the retest phase for various objective reasons (*e.g.*, work commitments, voluntary nature of participation). As this was a convenience sample tested through official examination following the actual training of potential CFRs, we were unable to expand the sample size. Nevertheless, the present results, which are also confirmed by the acceptable level of statistical power, are a clear indication that the better knowledge retention of the intervention group cannot be attributed to chance. The second limitation of our study was that knowledge retention was measured only by test scores, *i.e.*, by assessing the level of theoretical knowledge achieved. Further studies should be conducted to verify whether the above effect also applies to retention of practical knowledge and skills. This could be achieved by checking the level of acquired skills in CPR and AED use on a simulator after a certain period after training (six months in our case). The third limitation concerned the study design itself. Based on our results, it is currently not possible to determine whether the improvement in knowledge retention was due to the use of e-learning or to repetition of information alone. Therefore, further studies should be conducted to better investigate the actual impact of e-learning use on knowledge retention. One control and two intervention groups should be used: in the first group, participants would attend a supplemental e-learning course (as in our study), while in the second group, they would attend a revision of the information at the same time as the first group. However, due to the small number of participants, we were not able to implement such a study design. Last but not least, this study lacks the pre-test that would provide us with useful information about the participants' knowledge before the training. In addition, we did not consider in the study the experience of our participants with CPR before the beginning of the course or before the re-test, which could affect the retention of knowledge of basic life support. It is therefore necessary to consider these elements in future studies.

5. Conclusions

The results of our study provide compelling evidence that the use of e-learning to supplement face-to-face training in CPR and AED can improve knowledge retention among course participants, as demonstrated on the population of CFRs. The use of e-learning can contribute significantly to improving of the desired outcomes of such trainings. However, before drawing further conclusions, our study should be replicated in different settings to further verify the mentioned effect and to perform a meta-analysis of these studies.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

DS—performed the education and collected the data. DS and BŽ—analyzed the data. All authors (IK, DS and BŽ) designed the research study and the e-learning course. All authors (IK, DS and BŽ) wrote, read, and approved the submitted manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted under the supervision of the Red Cross of Ilirska Bistrica, Slovenia, which approved the study (approval dated 05 May 2017). Participation in the study was voluntary; participants had the right to withdraw from the study at any time without consequences. None of the participants refused to participate in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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